TITLE

ORGANIC ELECTROLUMINESCENT DEVICE BASED ON PYRENE DERIVATIVES

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to pyrene based compounds and materials and their use in organic light emitting devices. These pyrene based compounds and materials can be used as the emissive layer, electron transport layer, hole transport layer or one or more of such layers, although their use as a blue emissive layer is preferred. These compounds can also be used as a host or dopant material for one or more of such layers.

Description of the Related Art

[0002] Organic light emitting devices (OLEDs) typically comprise a layer of emissive material between an anode and a cathode. When a bias is applied across the electrodes, positive charges (holes) and negative charges (electrons) are respectively injected from the anode and cathode into the emissive layer. The holes and the electrons form excitons in the emissive layer to emit light.

[0003] Electrodes are chosen to facilitate charge injection. A transparent indium-tin-oxide (ITO) anode has a relatively high work function and is therefore suitable for use as a hole injection electrode, while low work function metals such as Al, Mg and Ca are suitable for injection of electrons.

[0004] To improve the power efficiency of an OLED, it is frequently desirable to enhance charge injection at the electrode interface. Hole transport layers and electron transport layers may be added adjacent to the respective electrodes to facilitate charge transfer. Depending upon whether hole transport or electron transport is favored, the light emissive layer may be located closer to the anode or the cathode. In some instances, the emissive layer is located within the hole transport or electron transport layer.

[0005] Improved performance can be obtained if blocking layers are provided to block against the injection of either holes or electrons from the adjoining layer and their subsequent escape from the device. Likewise, a modifying layer may be used to improve the contact with one or both of the electrodes, or to improve the interface between two other layers.

[0006] Some of these layers can be combined. For example, a double-layered structure is fabricated from a combined hole-injecting and transporting layer together with a combined electron-transporting and light-emitting layer. Likewise, a triple-layered structure is composed of a hole-injecting and transporting layer, a light-emitting layer, and an electron-injecting and transporting layer.

[0007] Hole transport layers may include triarylamine-based materials, although many other hole transport materials are known. Likewise, an aluminum quinolinolate complex known as AlQ_3 is a well known electron-transport material which has been used in OLEDs, although other electron transport materials are known.

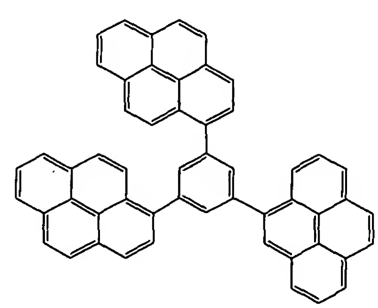
[0008] Emissive materials having widely varied structures are known in the art and are generally selected based on color, brightness, efficiency and lifetime. These emissive materials may themselves also have electron transport or hole transport characteristics.

[0009] In addition, it is possible to form these layers from a "host" material doped with another material (the "guest" material) designed to achieve the desired effect of the layer (for example, to achieve a hole transport effect, an electron transport effect, or an emissive effect). In the case of an emissive guest-host system, the host must be able to transfer energy to the guest so that a maximum amount of energy contributes to emission by the guest rather than being absorbed by the host.

[0010] Fused aromatic ring compounds have been used in the layers of organic light emitting devices. Their advanced pi-delocalization system, high mobility and good photoluminescence are desired qualities for OLED application.

[0011] Pyrene is a fused aromatic ring compound. In solution, pyrene fluoresces purple blue, yet in solid state it fluoresces white. This white light is due to intermolecular aggregation.

[0012] Since blue emissive materials are desired, it has been considered to prevent aggregation in pyrene by attaching pyrene to a benzene ring at the 1, 3, and 5 position to make 1,3,5-tripyrene benzene (3TPB), as follows:



[0013] This arrangement results in a good blue emissive material with a peak emission at 450nm. However, closer investigation of 3TPB reveals that the compound still has a minor aggregation problem in its solid state, resulting in a shoulder emission at 482nm and reduced blue color purity

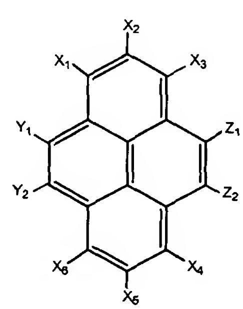
[0014] There continues to be a need for OLED materials exhibiting thermal stability, having bright, high purity luminescent emission, and for materials which contribute to greater luminescence per injected charge. There is particularly a need for OLED materials which provide a good blue emission.

SUMMARY OF THE INVENTION

[0015] As noted above, pyrene based materials are capable of producing blue emissions that have good color purity. However, due to the tendency to aggregate, the blue emission of these materials is tainted by emissions of other wavelengths.

[0016] It is an object of the present invention to provide a pyrene based material for OLED application which will have reduced aggregation problems and, hence, improved blue emission purity.

[0017] Thus, in one aspect, the invention is a pyrene based compound according to the following general formula (I):



(I)

wherein Z_1 represents a hydrogen atom, deuterium atom, oxygen atom, silicon atom, selenium atom, substituted or unsubstituted aryl group, substituted or unsubstituted heteroaryl group, substituted or unsubstituted aryl amine or a combination thereof, and Z_2 represents a hydrogen or deuterium atom;

wherein one of Y_1 and Y_2 represents a hydrogen atom, deuterium atom, oxygen atom, silicon atom, selenium atom, a substituted or unsubstituted aryl group, substituted or unsubstituted heteroaryl group, substituted or unsubstituted aryl amine or a combination thereof, and the other of Y_1 and Y_2 represents a hydrogen or deuterium atom;

wherein X_1 through X_6 independently represent hydrogen atoms, deuterium atoms, alkyl groups or aryl groups, and at least one of X_1 through X_6 represents a bulky alkyl group or bulky aryl group; and

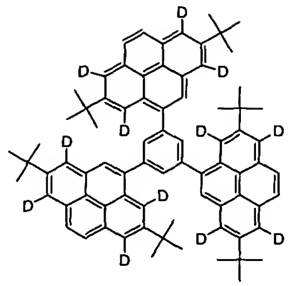
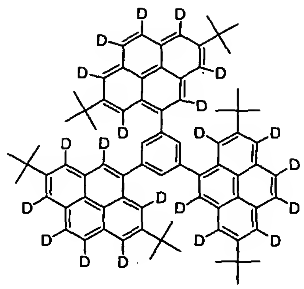
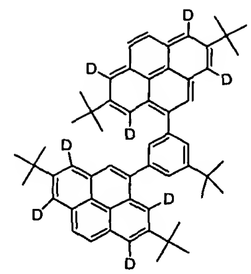
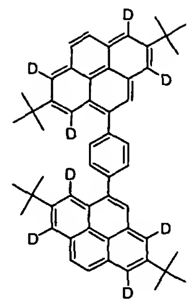
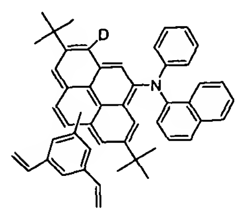
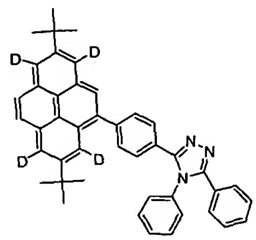
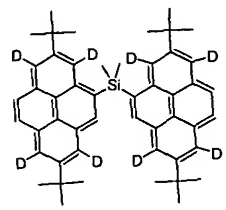
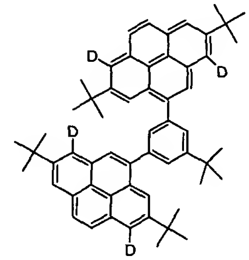
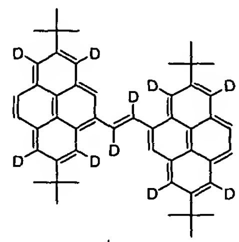
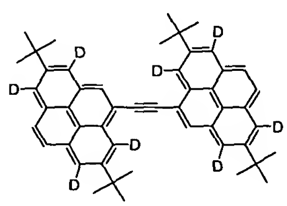
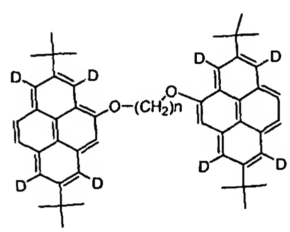
wherein at least one of X_1 through X_6, Y_1,Y_2, Z_1, and Z_2 represents a deuterium atom.

[0018] In one embodiment of the present invention, Z_1, Y_1 and Y_2 independently represent hole injection chromophores, electron injection chromophores, or both. Z_1, Y_1 and Y_2 independently may also represent a cross-linking group. Preferably, the cross-linking group comprises a di-vinyl group. Finally, Z_1, Y_1 and Y_2 independently may represent a benzene ring substituted with one or two pyrenyl groups.

[0019] Optionally, X_1 through X_6 independently represent a tert-butyl group or a triphenyl silane.

[0020] In a preferred embodiment, both X_2 and X_5 represent a bulky alkyl group or bulky aryl group and more preferably, the same bulky alkyl or bulky aryl group.

[0021] The following structures are examples of the pyrene based compounds of the present invention.

[0022] Another aspect of the present invention is an OLED in which at least one organic layer is sandwiched between an anode and a cathode, and in which the organic layer includes a pyrene based compound as described above. The organic layers of an OLED in which the compound can be used include a hole transport layer, an electron transport layer or an emissive layer.

[0023] In an emissive layer, the pyrene based compound can be used directly as the emissive layer or can be used as a host material for an emissive dopant in a case where the emissive layer comprises a pyrene based host plus an emissive dopant. The emissive dopant can also be the pyrene based compound described above. Preferably, the emissive layer emits in blue wavelengths.

[0024] Alternatively, the pyrene based compound can be used directly as the hole transport layer, the electron transport layer or both. Furthermore, the compound

can form a charge transport host material in a case where the charge transport layer comprises a host material plus a charge transport dopant.

[0025] Optionally, the OLEDs of the present invention contain a pyrene based compound wherein Z_1, Y_1 and Y_2 independently represent hole injection chromophores, electron injection chromophores, or both.

[0026] This brief summary has been provided so that the nature of the invention may be understood quickly. A more complete understanding of the invention can be obtained by reference to the following detailed description of the preferred embodiment thereof in connection with the attached drawings.

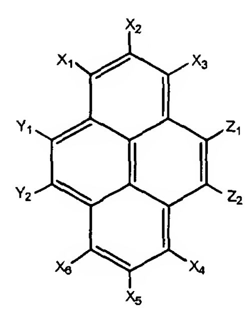
BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Figure 1 is a schematic cross-sectional view of a three layer organic light emitting device.

[0028] Figure 2 is a schematic cross-sectional view of a single layer organic light emitting device.

DETAILED DESCRIPTION OF THE INVENTION

[0029] The pyrene based compound of the present invention has the following general formula (I):



(I)

[0030] wherein Z_1 represents a hydrogen atom, deuterium atom, oxygen atom, silicon atom, selenium atom, substituted or unsubstituted aryl group, substituted or

unsubstituted heteroaryl group, substituted or unsubstituted aryl amine or a combination thereof, and Z_2 represents a hydrogen or deuterium atom;

wherein one of Y_1 and Y_2 represents a hydrogen atom, deuterium atom, oxygen atom, silicon atom, selenium atom, a substituted or unsubstituted aryl group, substituted or unsubstituted heteroaryl group, substituted or unsubstituted aryl amine or a combination thereof, and the other of Y_1 and Y_2 represents a hydrogen or deuterium atom;

wherein X_1 through X_6 independently represent hydrogen atoms, deuterium atoms, alkyl groups or aryl groups, and at least one of X_1 through X_6 represents a bulky alkyl group or bulky aryl group; and

wherein at least one of X_1 through X_6, Y_1,Y_2, Z_1, and Z_2 represents a deuterium atom.

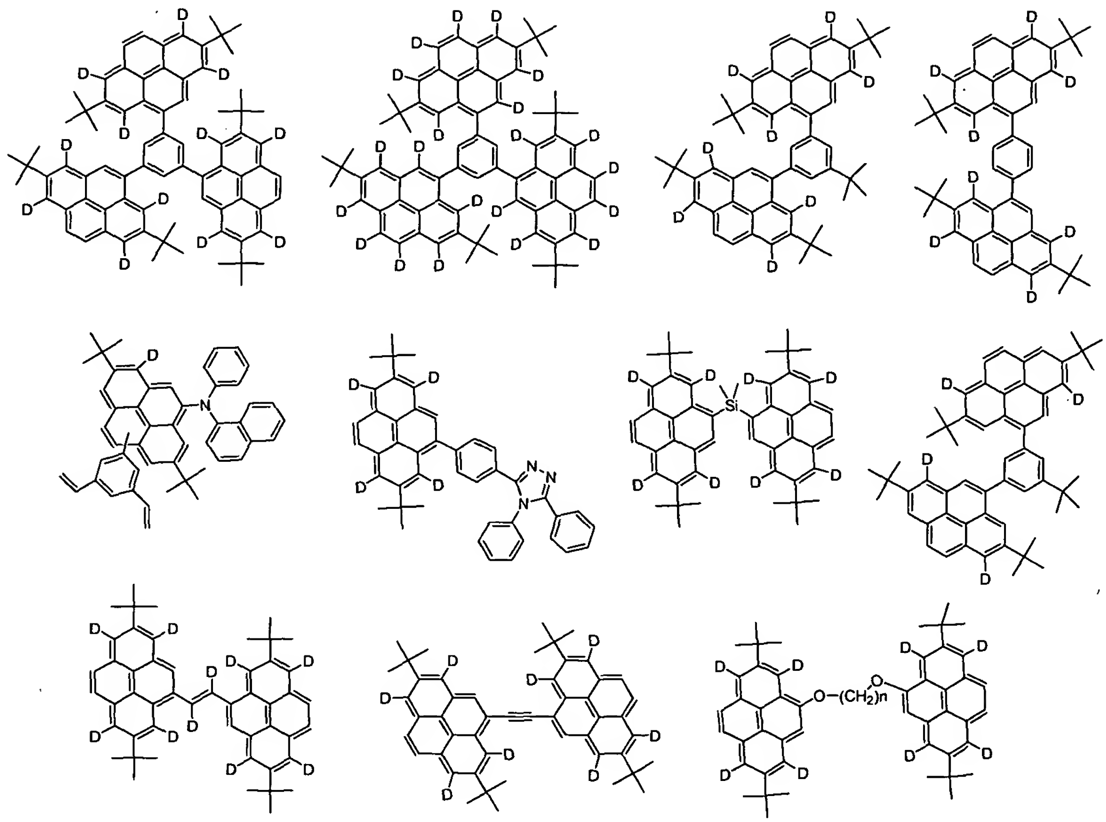
[0031] In one embodiment of the present invention, Z_1, Y_1 and Y_2 independently represent hole injection chromophores, electron injection chromophores, or both. Z_1, Y_1 and Y_2 independently may also represent a cross-linking group. Preferably, the cross-linking group comprises a di-vinyl group. Finally, Z_1, Y_1 and Y_2 independently may represent a benzene ring substituted with one or two pyrenyl groups.

[0032] Optionally, X_1 through X_6 independently represent a tert-butyl group or a triphenyl silane.

[0033] In a preferred embodiment, both X_2 and X_5 represent a bulky alkyl group or bulky aryl group and more preferably, the same bulky alkyl or bulky aryl group.

[0034] A pyrene based compound expressed according to the above formula can be made with methods known in the art.

[0035] Some preferred pyrene based compounds represented by the above formula include:



[0036] A characteristic of a pyrene based compound expressed according to the above formula is reduced intermolecular aggregation as compared to 3TPB, due to the substitution of bulky substituent groups. Such a pyrene based compound exhibits the quality of a pure blue color without aggregate emission when fluorescing. As a result, an advantage of the disclosed pyrene based materials for use in OLEDs according to the invention is that they emit a good blue hue without white photoluminescence.

[0037] The pyrene based compound expressed according to the above formula can be used in the hole transport layer, electron transport layer or emissive layer of an OLED.

[0038] An OLED may be a multi-layer device, such as a three layer device, shown in Figure 1, as described more fully below, or a single layer device, shown in Figure 2.

[0039] In Figure 1, a three layer device comprises an emissive layer 103 sandwiched between an electron transport layer 105 and a hole transport layer 102. Additionally, an electron transport layer 105 and hole transport layer 102 are sandwiched between a cathode 106 and an anode 101.

[0040] Various procedures for the fabrication of an OLED exist, including the following general procedure: To construct a three layer device, as in Figure 1, a clean substrate coated with a patterned layer of indium tin oxide (ITO) is first obtained. Next, the substrate is treated with O_2 plasma for 1-5 minutes. Afterwards, the substrate is placed in a thermal evaporator and the pressure is lowered. Then, organic and metallic layers are evaporated onto the substrate at a rate approximately between 1-3 Å/s. These organic and metallic layers may vary depending upon the desired OLED. A hole transport layer 102 is usually evaporated with a thickness of ~200 Å. Next, an emissive layer 103 is evaporated, usually with a host and dopant. Normally, 100-400 Å of the emissive layer is deposited. Then, an electron transport material is evaporated to form a layer 105 that is usually 200-400 Å thick. After the evaporation of the preferred organic and metallic layers, a mask is placed adjacent to the layer to define where metal areas corresponding to cathodes are to be evaporated. Then, about 120 Å of a Li-Al alloy is evaporated to improve electron injection into the device. Finally, after about 1500 Å of Al is deposited, the evaporator is allowed to cool.

[0041] Fabrication of a suitable hole transport, electron transport or emissive layer using the pyrene based compound can be accomplished through the use of thermal deposition in a vacuum, or by spin coating of a solution thereof.

[0042] In Figure 2, a single layer device comprises a combined layer 203, comprising an emissive layer and an electron transport or hole transport layer, sandwiched between a cathode 206 and an anode 201.

[0043] For either a multi-layer device or a single layer device, in the emissive layer, the pyrene based compound can be used directly as the emissive layer or can be used as a host material for an emissive dopant in a case where the emissive layer comprises a pyrene based host plus an emissive dopant. The emissive dopant can also be the pyrene based compound described above.

[0044] Alternatively, the pyrene based compound can be used directly as the hole transport layer, the electron transport layer, or both. Furthermore, the pyrene based compound can form a charge transport host material in the case where the charge transport layer comprises a host material plus a charge transport dopant.

[0045] It is to be understood that the invention is not limited to the above-described embodiments and that various changes and modifications may be made by those of ordinary skill in the art without departing from the spirit and scope of the invention.